

THE PUPAL COCOON OF THE CAT FLEA,  
*CTENOCEPHALIDES FELIS* (BOUCHÉ)  
(SIPHONAPTERA: PULICIDAE):  
A BARRIER TO ANT PREDATION

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*Abstract.*—The pupal cocoon of the cat flea, *Ctenocephalides felis*, serves as a protective barrier to predation by the Argentine ant, *Iridomyrmex humilis*. The ants readily foraged on exposed eggs, larvae and pupae. However, intact pupal cocoons constructed of sand, soil or cotton fibers provided protection from foraging ants. The pupal cocoon itself is not air or water tight or repellent, indicating physical protection rather than a chemical barrier.

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Many holometabolous insects, including fleas, construct pupal cocoons that are thought to protect the pupae from natural enemies, temperature and moisture extremes, and physical damage (Chapman, 1982; Richards and Davies, 1977). Those functions, however, have not been supported by adequate data.

The cocoons of Siphonaptera, constructed by the third-instar larvae, are typically composed of silk and debris. Cocoons of the cat flea, *Ctenocephalides felis* (Bouché), may be located in soil, on vegetation, under rocks and on a number of man-made substrates such as carpet, furniture fabrics, and animal bedding. The cocoon surrounds the third-instar larvae, prepupae, pupae and pre-emergent adult for up to 122 days (Silverman et al., 1981), but development can proceed without the cocoon (Silverman, 1981).

The present study was initiated following observations of predation on eggs, larvae, and unenclosed pupae of *C. felis* by the Argentine ant, *Iridomyrmex humilis* (Mayr), in an outdoor test. Ant predation has been shown to cause significant reductions in prey populations including ticks (Harris and Burns, 1972; Butler et al., 1979), scale insects (Bartlett, 1961), houseflies (Pimentel, 1955), rootworm eggs (Risch, 1981), boll weevils (Sterling, 1978) and at least 32 other arthropod species (Risch and Carroll, 1982). Herein we document the protective function of the cat flea pupal cocoon against ant predation and examine some possible mechanisms to account for this phenomenon.

#### MATERIALS AND METHODS

Fleas were obtained from laboratory cultures maintained as described by Silverman et al. (1981). Eggs; second instar larvae; pupae dissected from their cocoons; pupae in partially opened cocoons; and pupae completely enclosed in cocoons composed of cotton fibers, sand or soil, were used in the experiments.

Fleas, empty cocoons and cocoon-size cotton fiber, sand or soil models were presented to trailing *I. humilis* workers on or ca. 4 cm away from a main trail. The interval between the time when the flea or model was presented to the ants and when it was picked up was recorded. If the flea or model was not picked up or moved away from the trail within 15 min, it was scored as a non-response.

The effectiveness of the cocoon in preventing ant predation by random foraging and subsequent worker recruitment was determined by presenting fleas near the ant nest. On each of 5 days over a 2 week period, 20 specimens of each flea stage were placed inside 6-cm-diam  $\times$  2-cm tin containers 1.5 m from the entrance of an *I. humilis* colony. The number of specimens of each stage or variable remaining in each container after 24 hours was recorded.

## RESULTS AND DISCUSSION

Cat flea eggs, larvae and naked pupae were picked up along a foraging trail of *I. humilis* workers within one minute and taken into the ant colony (Table 1). Up to 6 ant workers required nearly 5 min to remove pupae from partially opened cocoons. None of the 3 types of cocoons (cotton, sand or soil) which contained pupae were picked up by the ants within 15 min. Similarly, ants ignored or discarded models the size and color of cocoons.

All exposed stages placed 1.5 m from the ant nest entrance were removed by the ants on each of the 5 test days. No pupae in cocoons constructed of cotton fibers, sand or soil were removed during the first 3 test days, but on the last 2 days all sand cocoons were removed. We subsequently discovered that sand cocoons presented during the first 3 days were constructed exclusively of sand and silk while cocoons presented to the ants on days 4 and 5 were composed of sand and silk in addition to larval rearing media containing beef blood, Wheat<sup>®</sup> and dog chow. When the test was repeated comparing 100 cocoons constructed of sand or sand and media, 61% of the cocoons made of sand and media were removed while cocoons made with sand were left intact.

Several mechanisms to explain the protection afforded by the cocoon were considered. Visual camouflage was probably not important since the color and form of the cocoon contrasted sharply with the substrate. Since ants aggregated around partially opened cocoons while attempting to remove pupae but ignored cocoons placed directly on a trail it is unlikely that the cocoon contained a chemical repellent. Silverman (1981) showed that the pupal cocoon of *C. felis* is permeable to air and water vapor suggesting that the cocoon does not mask possibly attractive odors of the enclosed pupae. Ants ignored or discarded intact cocoons and similar size cocoon models. Cocoons constructed of sand and larval media were removed because the ants perceived food incorporated into the case of the cocoon, not because of the presence of a pupa. Larval media particles the size of cocoons were removed from ant trails as rapidly as naked pupae.

The cocoon of *C. felis* affords the pupae protection from *I. humilis* and possibly other ant predators. Whether the pupal cocoons of *C. felis* and other Siphonaptera evolved in response to attack by ants or other predators is unknown. Although ants and fleas often occur in the same location, the relationship between these two groups has received very little study. Fox and Garcia-Moll (1961) reported attack of adult and larval oriental rat flea, *Xenopsylla cheopis* (Rothschild), by the

Table 1. Response of *I. humilis* workers to immature fleas and cocoon models placed on or near a foraging trail.

Stage and Condition or Model	No. Minutes ( $\bar{x} \pm SD$ ) <sup>a</sup> Until Removed by Ants
Egg	0.5 $\pm$ 0.3
Larva	0.6 $\pm$ 0.2
Naked pupa	0.9 $\pm$ 0.7
Pupa in partially opened cocoon	4.7 $\pm$ 2.1
Pupa/cotton fiber cocoon	Ignored or discarded <sup>b</sup>
Pupa/sand cocoon	Ignored or discarded
Pupa/soil cocoon	Ignored or discarded
Cocoon size cotton, sand or soil model	Ignored or discarded

<sup>a</sup> Mean and standard deviation based on  $n = 20$ .

<sup>b</sup> Ignored for at least 15 min or removed up to 10 cm from the trail.

crazy ant, *Paratrechina longicornis* (Latreille). They found *P. longicornis* in 43% of rat nests and speculated that ant predation might be partly responsible for periodic reductions in rat flea populations in Puerto Rico and a concomitant reduction in the incidence of murine typhus.

When considering the adaptive significance of the cocoon relative to ant predation, the location of the cocoon is critical. If pupation occurs in areas inaccessible to ants, then a cocoon providing defense from ants would be unnecessary. We found that of 93 third-instar larvae placed on 2.5-cm-diam plugs of hybrid bermuda turf, 50 pupated on or between the blades above ground level (accessible to ants) while the remainder pupated in the soil between the roots. Every pupa was enclosed within a cocoon. Silverman et al. (1982) found the dauerlarvae of the soil-dwelling entomogenous nematode, *Neoaplectana carpocapsae* Weiser, readily penetrated *C. felis* cocoons and infected both prepupae and pupae placed in moist soil. Pupation in soil may therefore be more hazardous to the flea than pupation above ground where *I. humilis* workers normally forage.

Although not necessary for the development of *C. felis*, the cocoon is an important factor contributing to the survival of the cat flea and perhaps other flea species in at least two respects. The cocoon conceals its inhabitant from ants and possibly other macropredators, and by its protective nature allows for pupation in a number of locations not suitable for many micropredators.

#### ACKNOWLEDGMENTS

We thank Michael K. Rust, Donald A. Reiersen and Weste L. A. Osbrink for their critical review of the manuscript. The services of Mr. Matthew Lombard are also gratefully acknowledged.

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PROC. ENTOMOL. SOC. WASH.  
86(3), 1984, p. 663

#### NOTE

#### A new host for *Perilampus hyalinus* Say (Hymenoptera: Perilampidae)

*Perilampus hyalinus* Say (det. E. E. Grissell, Systematic Entomology Laboratory, USDA) was reared as a hyperparasite from puparia of *Senotainia trilineata* (Van der Wulp) and *S. vigilans* Allen (Diptera: Sarcophagidae: Miltogrammini) from cells of *Tachysphex terminatus* (Smith) and *Tachytes validus* Cresson (Hymenoptera: Sphecidae) at two central New York sites in 1981 and 1982. *P. hyalinus*, either as a primary or secondary parasite, may represent a species complex rather than a single species (Burks, in Krombein et al. 1979, *Catalog of Hymenoptera in America North of Mexico*, Vol. 2 (Aculeata), Smithsonian Inst. Press: 768-835). Host records on Miltogrammini exist only for *Perilampus* sp. and *P. hyalinus* on *S. trilineata* (Frisch, J. G. 1936. *Psyche* 43: 84-85; Frisch, 1938. *Am. Midl. Natur.* 19: 673-677; Medler, J. F. 1965. *Ann. Entomol. Soc. Am.* 58: 137-142). Thus *S. vigilans* is a new secondary host for *P. hyalinus*.

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